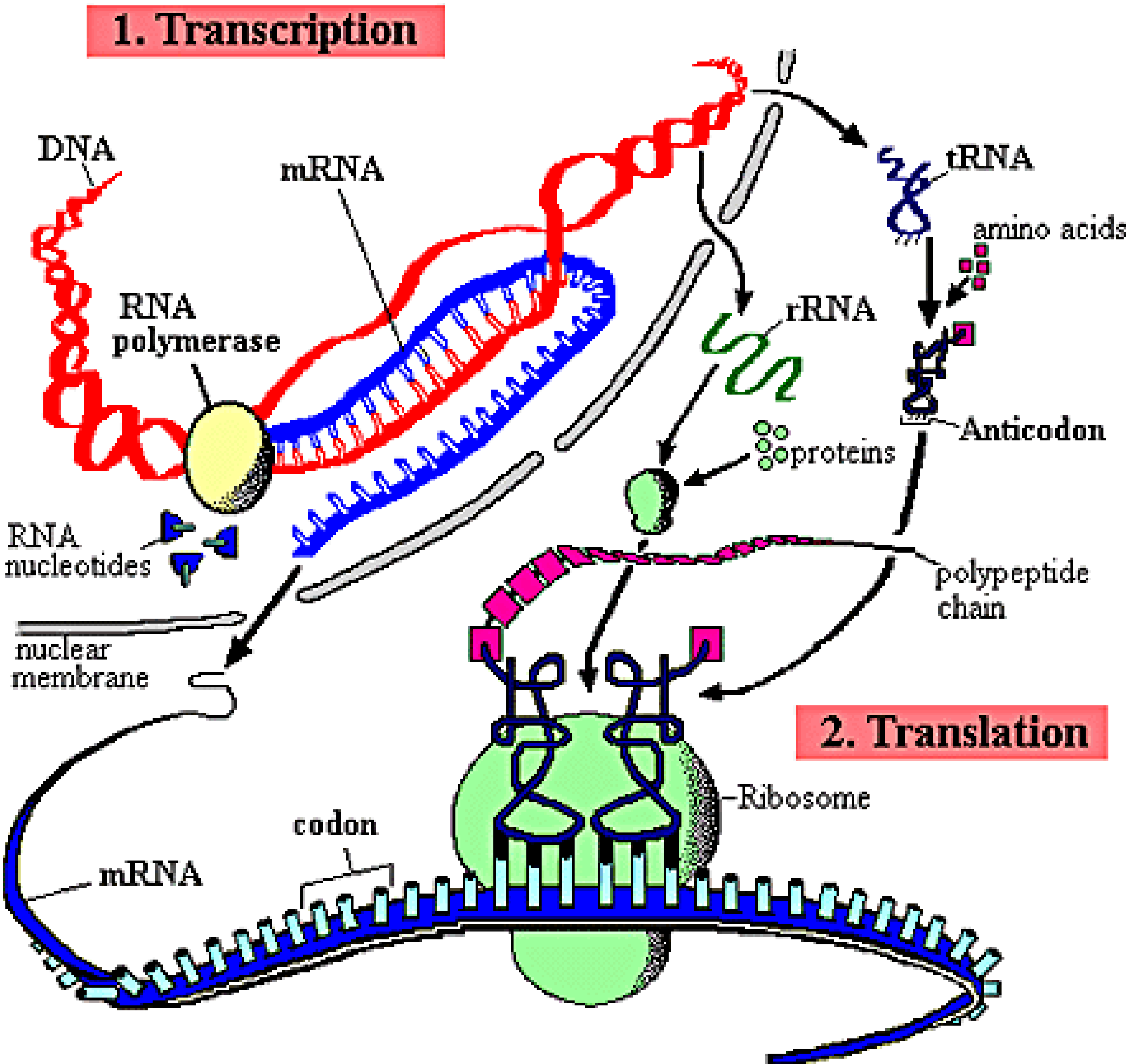
Unit 7 DNA, RNA and Protein Synthesis

Term 4 2011-12



Protein synthesis

DNA/RNA/GENETIC ENGINEERING
Chapter 9 and 10

12.A.4a Explain how genetic combinations produce visible effects and variations among physical features and cellular functions of organisms.

Unit Must Knows	*Key Vocabulary*
1. Students will be able to understand the DNA structure. a) Evaluate contributions of Watson and Crick and Wilkins and Franklin in the discovery of the double helix structure of DNA. b) Describe the structure of DNA, the nucleotides and base pairing rules (A-T, C-G). **2. Students will be able to understand the process of DNA replication.** a) Identify the role of enzymes in the replication of DNA. b) Describe how errors are corrected during DNA replication. c) Describe how complimentary base pairs guide DNA replication. d) Describe relationship of DNA replication and mutation. 3. **Students will be able to outline how genetic information from DNA is transferred to protein synthesis**. a) Compare the structure of RNA with DNA. b) Summarize the process of transcription. c) Compare the role of mRNA, tRNA and rRNA in translation. d) Describe the importance of learning about the human genome. Chapter 11 4. **Students will be able to understand the importance of DNA Technology and the Human Genome Project.** a) Describe the four major steps commonly used in creating recombinant DNA. b) Summarize importance of the Human Genome Project. c) Describe the uses of genetic engineering.	• DNA • Nucleotide • Deoxyribose • Nitrogen base • Base-pairing rules • DNA replication • Helicase • Replication fork • DNA polymerase • mutation • RNA • Transcription • Translation • Protein synthesis • Ribose • mRNA • rRNA • tRNA • RNA polymerase • Codon • Anticodon • Virulent • Vaccine • Introns • Exons Chapter 11 • Genome • Genetic engineering • Recombinant DNA • Clone • Vector • Plasmid • Human Genome Project

Test Prep CheckList

Have I completed…

Key Terms…

- ☐ **Completed** and **know** all the Word Parts for this unit and the unit before?
- ☐ **Defined** and **studied** (flash cards help) the Key Terms for the Unit?

Reading Circles…

- ☐ **Completed** each of the reading circles for each of the sections in the book?
- ☐ **Taken** and **corrected** each of the Reading Quizzes for each section in the book?

Must Knows…

- ☐ **Identified** and have **written** the appropriate Must Know on the top of each page in the packet
- ☐ **Studied**, **Know** and **asked questions** for each of the Must Knows for this Unit.

Notes…

- ☐ **Taken** Cornell Notes for each day of the unit.
- ☐ **Generated** at least 5 questions for each page of notes.
- ☐ **Summary** is written for each page of notes

Organization…

- ☐ Everyday's Must Knows and Homework is written on the calendar or in an assignment notebook.
- ☐ Cornell Notes are stored in binder.

Unit 7 DNA, RNA & Protein Synthesis Key Terms

Define the following…

- DNA
- Nucleotide
- Deoxyribose
- Nitrogen base
- Base-pairing rules
- DNA replication
- Helicase
- Replication fork
- DNA polymerase
- mutation
- RNA
- Transcription
- Translation
- Protein synthesis
- Ribose
- mRNA
- rRNA
- tRNA
- RNA polymerase
- Codon
- Anticodon
- Virulent
- Vaccine
- Introns
- Exons

Chapter 11

- Genome
- Genetic engineering
- Recombinant DNA
- Clone
- Vector
- Plasmid
- Human Genome Project

Bell Ringer Worksheet

Question:	**Date:**
Answer:	

Question:	**Date:**
Answer:	

Question:	**Date:**
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Question:	**Date:**
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Question:	**Date:**
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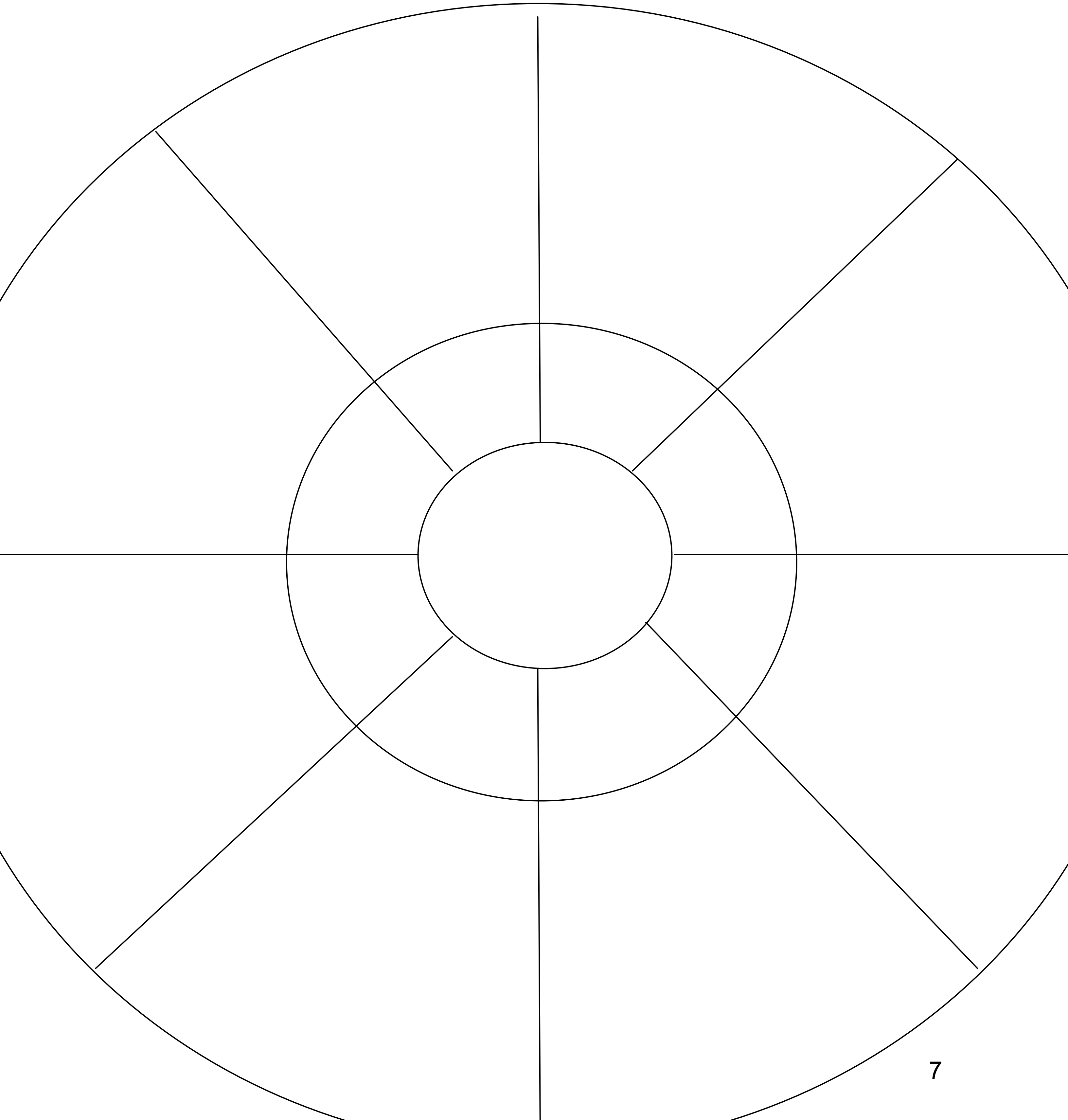
Must Knows:



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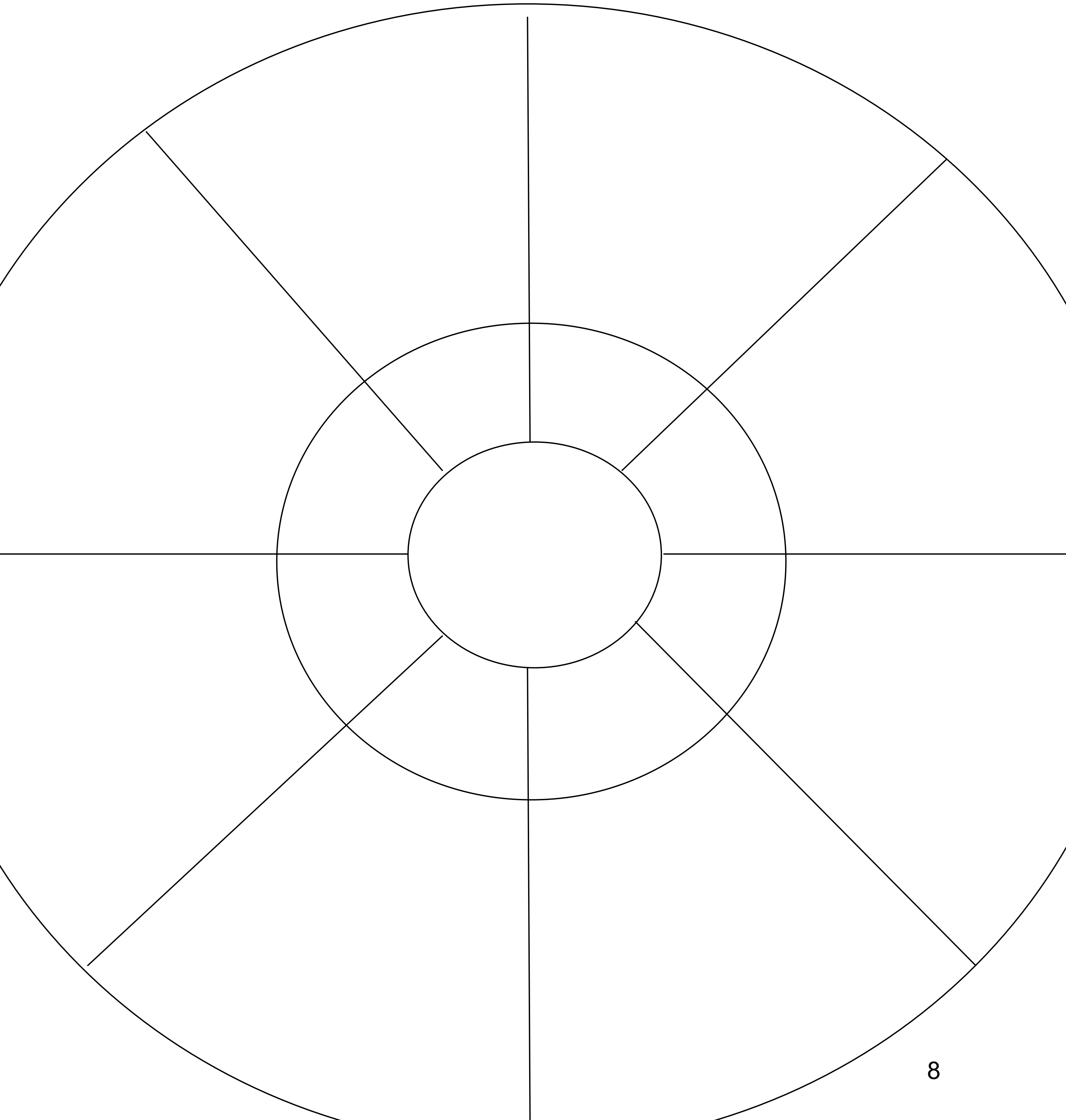

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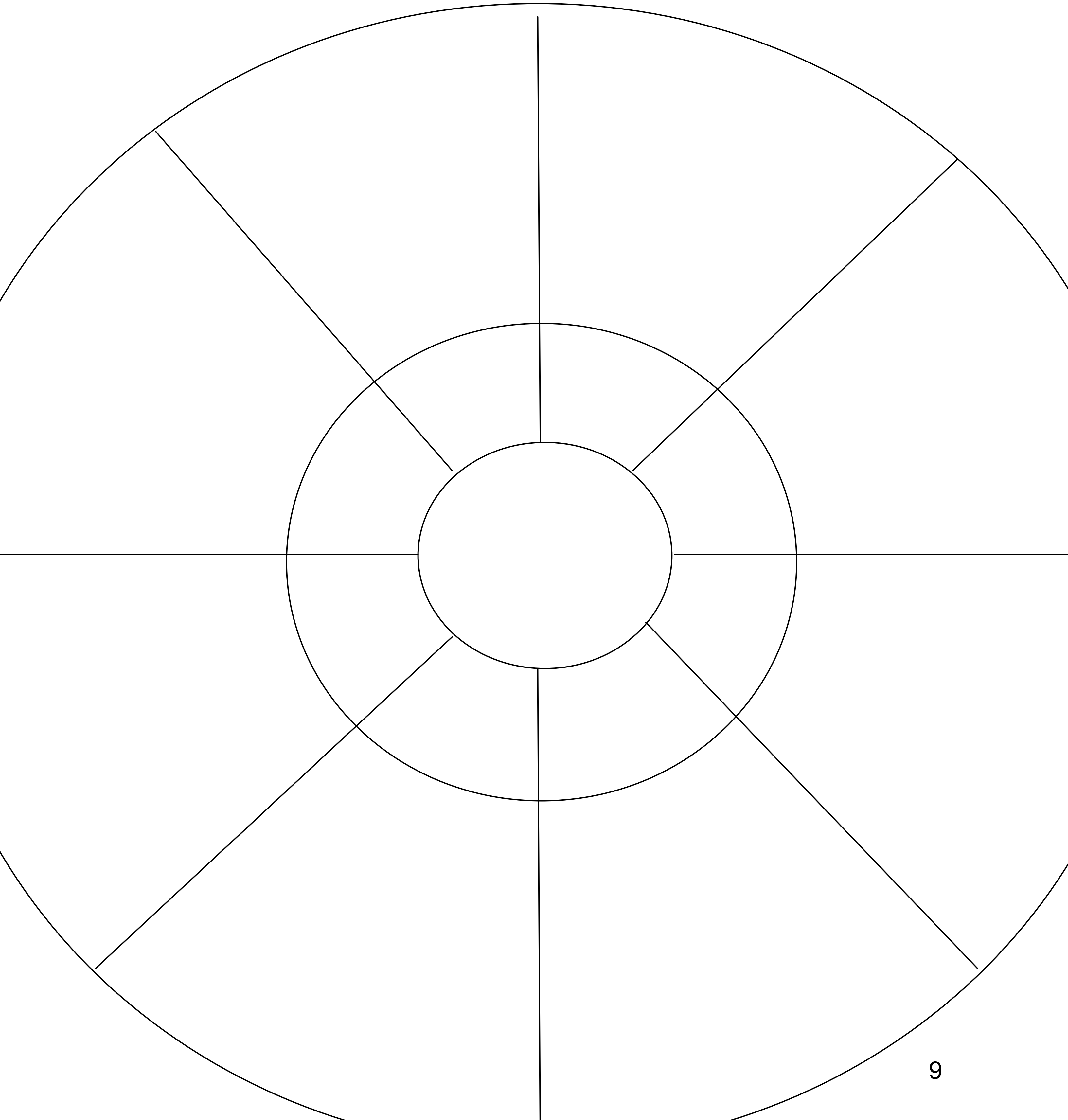

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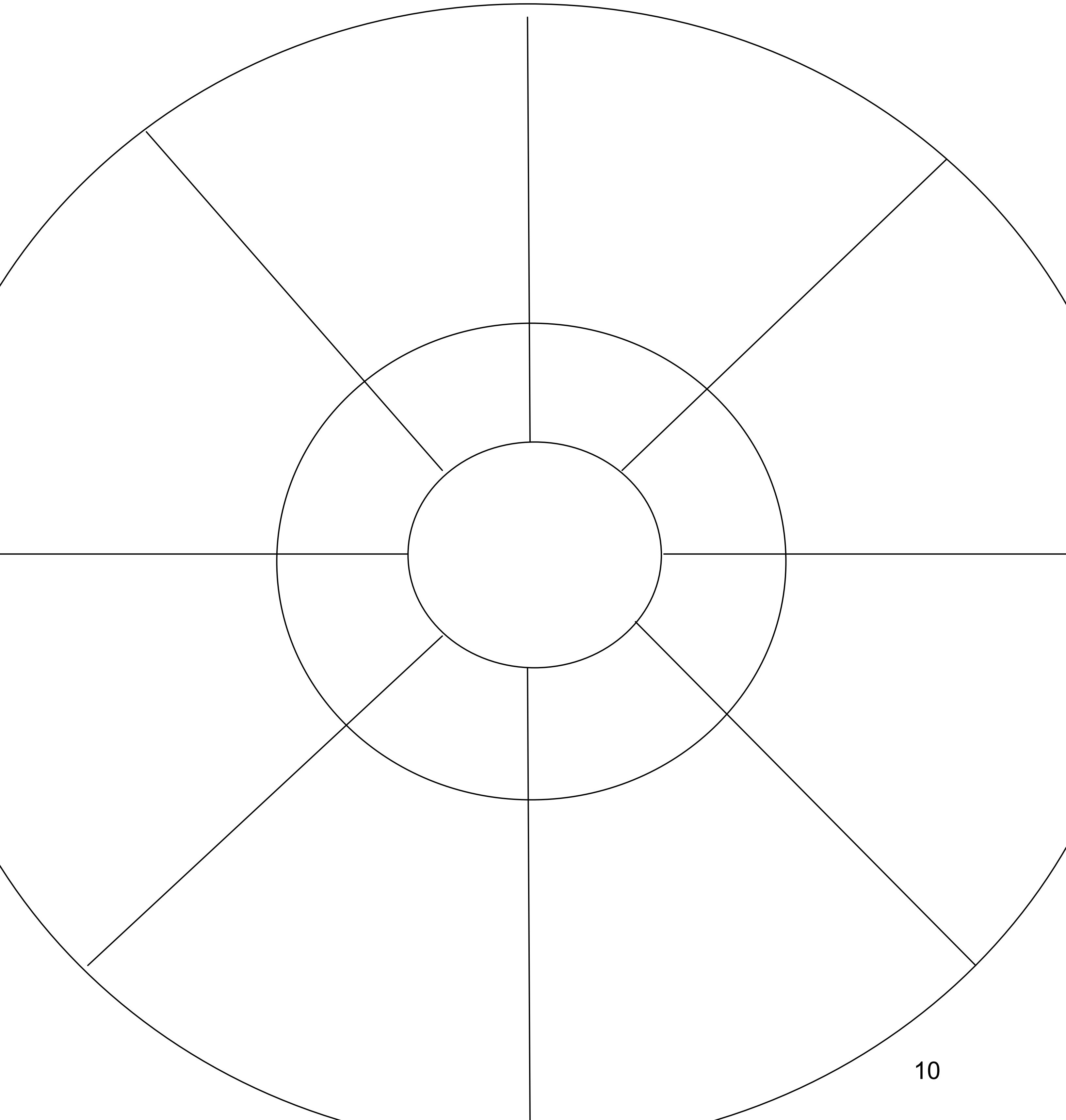

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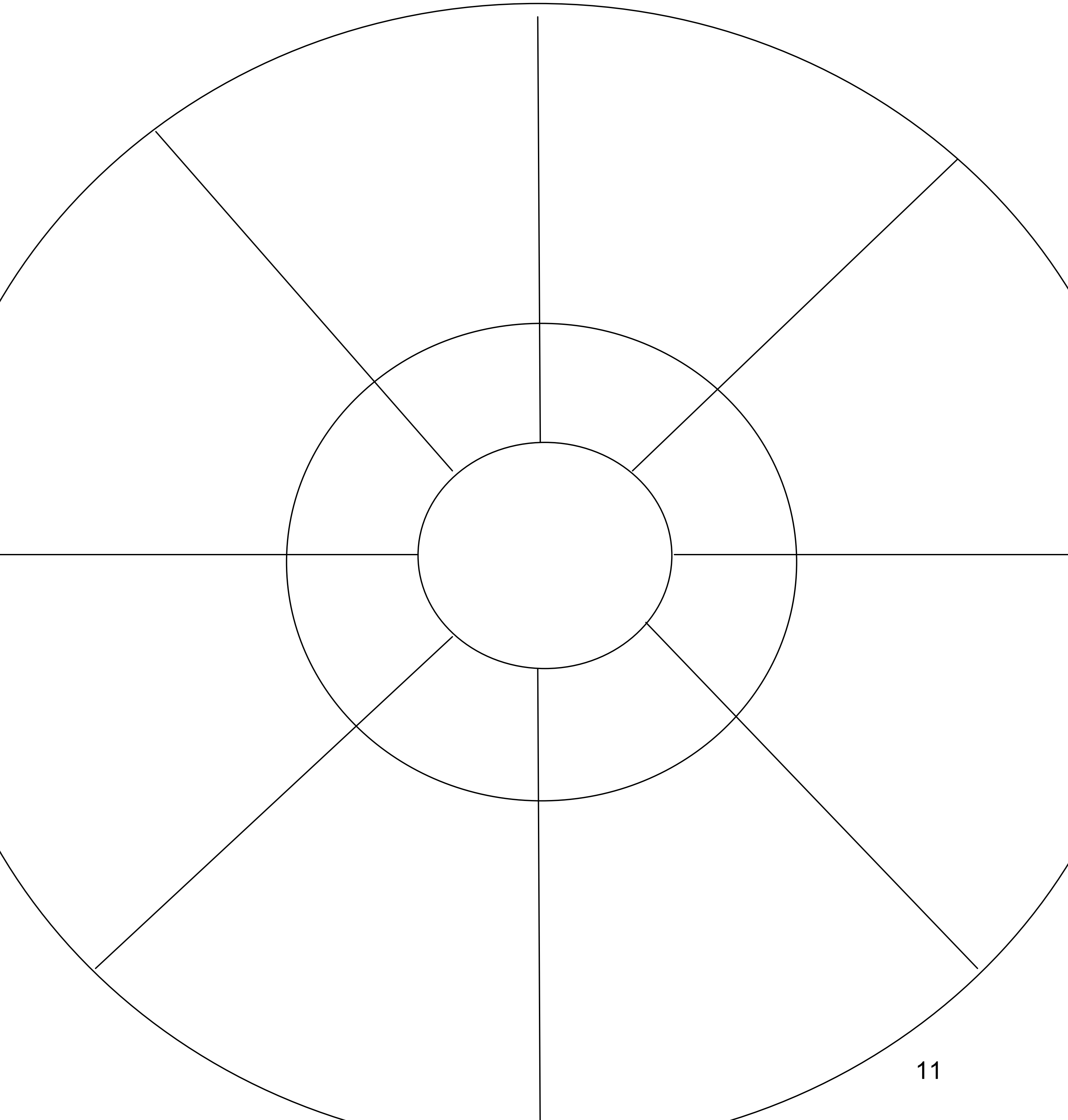
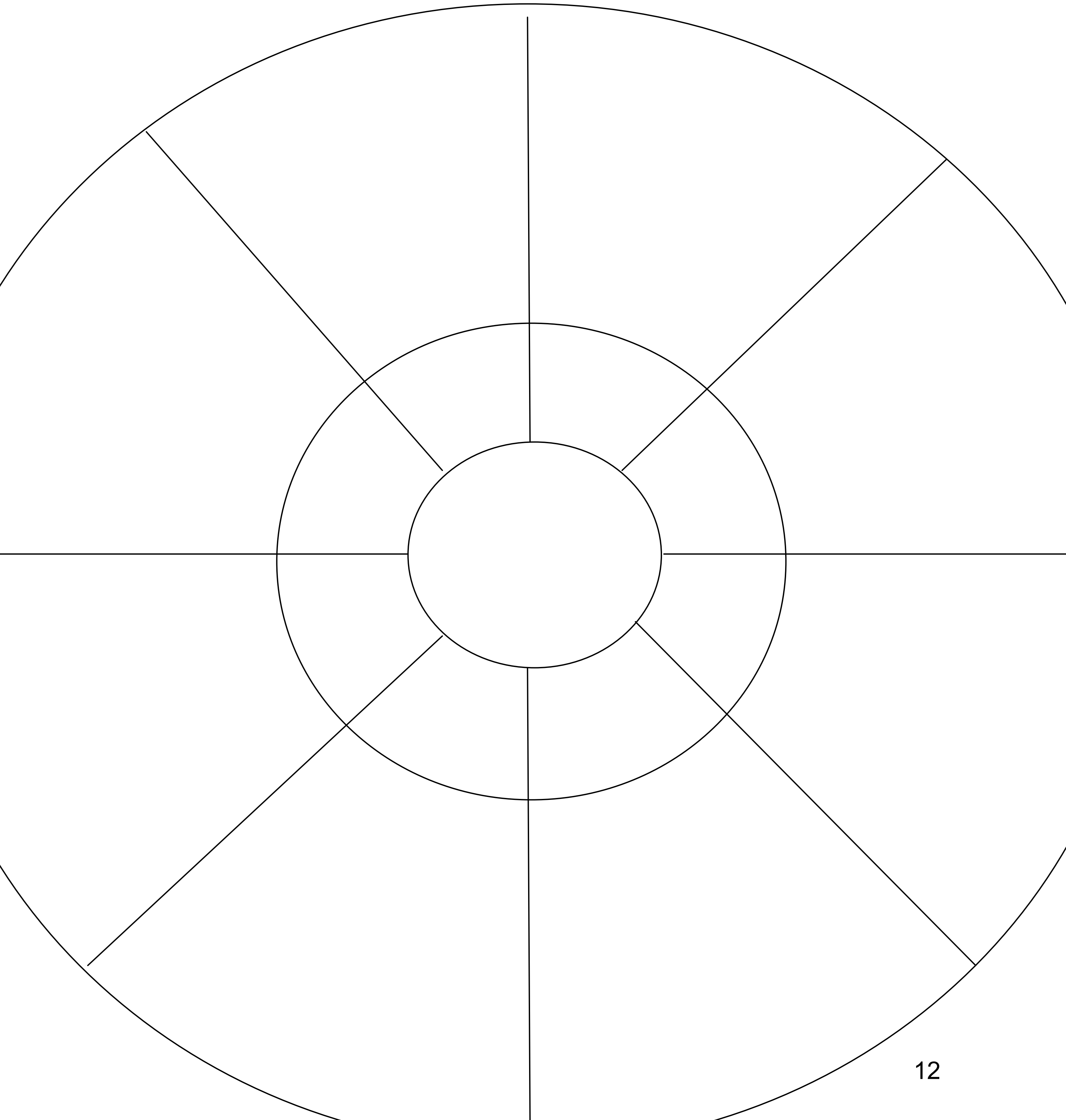


Must Knows:



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Date:_____________ Period:______

DNA Structure Quiz

(Use scientific terms only)

1. What does DNA stand for? ____
2. The four macromolecules are carbohydrates, lipids, proteins and

   ____
3. What is the monomer of DNA? ____________________________
4. What are the three parts that make the monomer of DNA?

   _______________________ _______________________ _________________
5. What are the four nitrogen bases according to shape?

   Purines _____________________ _____________________

   Prymidines _____________________ _____________________
6. What is the shape of DNA? __________________________________
7. Which two people are credited for discovering the shape of DNA?

   ____________________________ _____________________________
8. One strand of the double helix is _______________________ to the other strand?
9. What two parts make up the DNA backbone?

   ________________________________ _____________________________
10. What type of chemical bond holds together the base pairs?

   ____

Must Know Covered...

Chapter 4-1: Structure of DNA

Two types of nucleic acids exist: deoxyribonucleic acid (DNA) and ribonucleic acid (RNA). DNA is the genetic material of organisms, while RNA is used during the construction of proteins. This plate will examine the structure of DNA. RNA's structure is studied in a succeeding plate in this chapter.

This plate illustrates the components of a molecule of DNA. Letters have been correlated with the names of some of the components; most textbooks use these letter abbreviations. Light colors such as grays and yellows should be used for the first part of the plate.

DNA exists in the chromosome of the living eukaryotic cell, and in the cytoplasm of prokaryotic cells. DNA is composed of repeating units known as nucleotides. Each nucleotide has three components: a molecule of the carbohydrate deoxyribose, a phosphate group, and a nitrogenous base. At the upper portion of the plate, two nucleotides are shown. At the left is a nucleotide composed of a **phosphate group (P)**, a **deoxyribose molecule (D)**, and a nitrogenous base called **adenine (A)**. The three components should be lightly shaded to avoid obscuring their individual atoms.

The deoxyribose molecule contains a five-carbon carbohydrate ring bound to the phosphate group at its $-CH_2$ group. On its opposite side, the deoxyribose molecule is bonded to the adenine molecule. The adenine contains five nitrogen atoms, which is why it is called a nitrogenous base.

A second nucleotide is shown at the right. It consists of a nitrogenous base called **thymine (T)**, bonded to a deoxyribose molecule (D) which is inverted here. The deoxyribose is in turn bonded to a phosphate group (P). As before, light shading should be used to denote the three portions of the nucleotide.

Adenine and thymine nucleotides are held to one another by two **hydrogen bonds (H)**, one of which is indicated by an arrow, which should be colored boldly. Hydrogen bonds are weak chemical bonds formed between hydrogen and nearby electronegative atoms. In DNA, two hydrogen bonds exist between A and T, and three exist between G and C.

We will now examine how the nucleotides bind to one another to form DNA. Continue your coloring as you read, and use the same colors in the DNA molecule that you used for the nucleotides.

The four nitrogenous bases that make up DNA are thymine, adenine, **cytosine (C)**, and **guanine (G)**. Let's take a look at the DNA double helix.

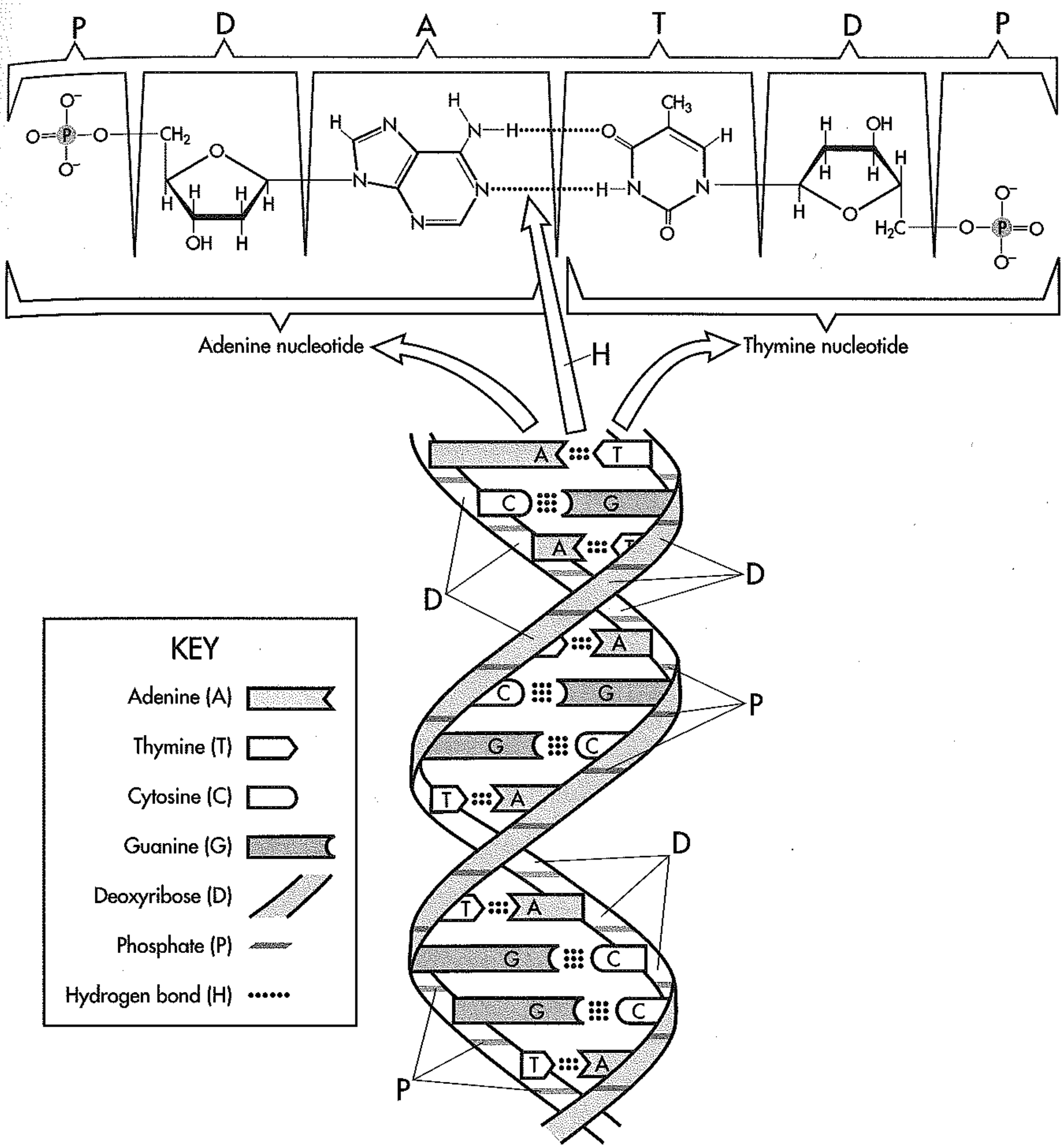
Begin at the top of the molecule, and note that the first nucleotide contains adenine (A), and that it is attached to deoxyribose (D). The deoxyribose is connected to a phosphate group (P) which in turn is connected to another deoxyribose molecule. The latter is connected to a cytosine (C) molecule, as well as another phosphate group (P). A deoxyribose molecule (D) follows, which is connected to an adenine (A). This pattern continues with alternating deoxyribose molecules and phosphate groups as the ribbon-like strand continues and curves. Each deoxyribose molecule is connected to one of the four nitrogenous bases.

Now move to the right side of the molecule and follow the ribbon, beginning at the upper right. As you follow it, note that it contains deoxyribose molecules that alternate with phosphate groups, and that again, connected to each deoxyribose molecule is one of the four nitrogenous bases. The second strand of DNA is very similar to the first strand.

We will complete the plate by noting how the two strands of DNA unite to form the double-stranded DNA molecule. If you have not yet completed your coloring of all the parts of the two strands, do so at this point. Then read below.

In the complete DNA molecule, two single strands oppose one another in a ladder-like arrangement, in which the nitrogenous bases line up opposite one another according to the principle of complementary base pairing. Adenine always lines up opposite thymine, and cytosine always lines up opposite guanine. As we mentioned earlier, hydrogen bonds then hold the bases together. The nitrogenous bases thus form rungs of a ladder.

Structure of DNA



Structure of DNA

- ○ Phosphate Group........P
- ○ Deoxyribose...........D
- ○ Adenine...............A
- ○ Thymine...............T
- ○ Hydrogen Bond.........H
- ○ Cytosine C
- ○ Guanine...............G

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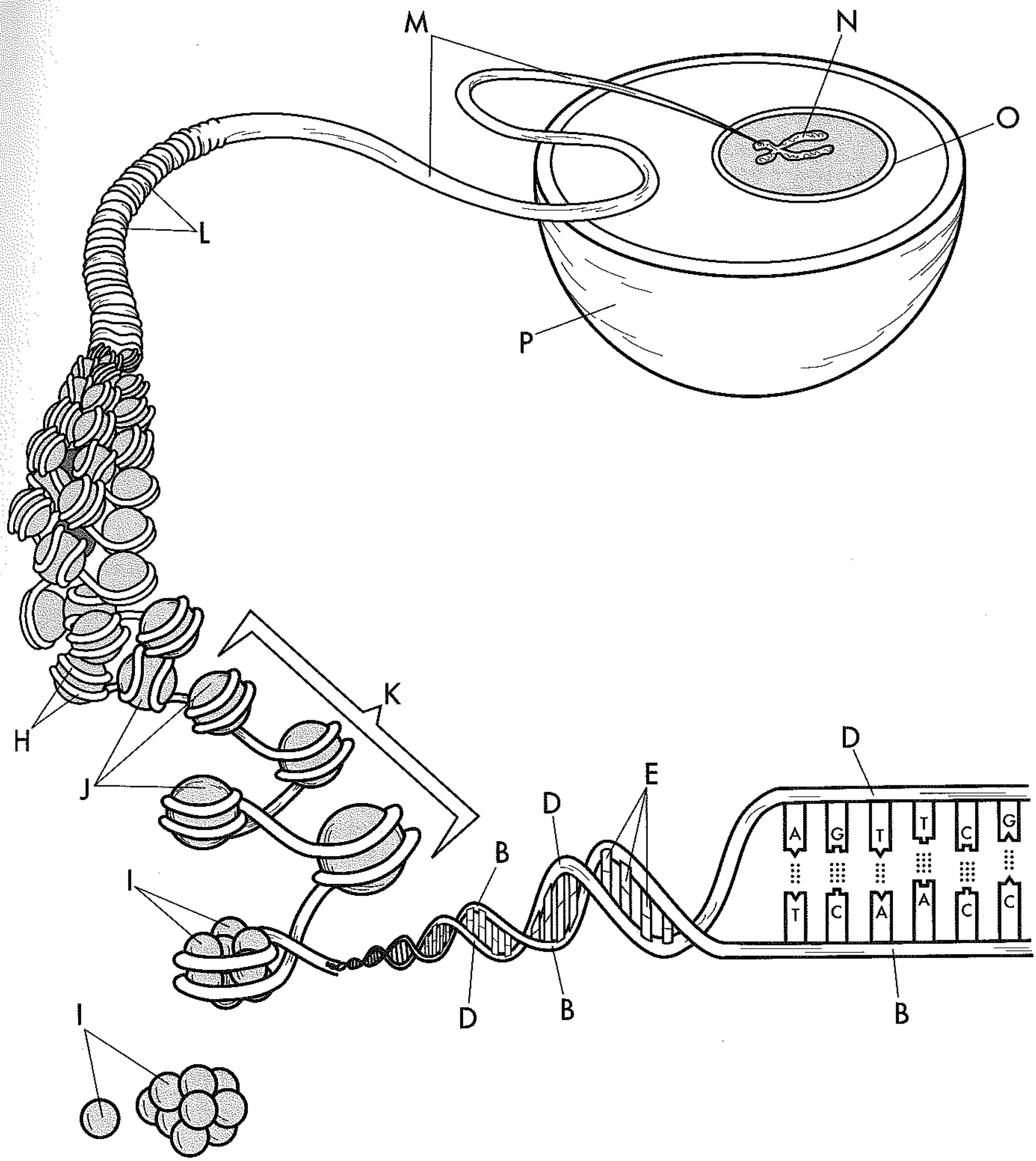
DNA and Chromosomes



DNA and Chromosomes

- ○ First Sugar-Phosphate Backbone ....D
- ○ Second Sugar-Phosphate Backbone ....B
- ○ Adenine................A
- ○ Thymine................T
- ○ Cytosine C
- ○ Guanine................G
- ○ Nitrogenous Bases......E
- ○ Two Loops of DNA ......H
- ○ Histone Proteins I
- ○ Condensed Histones ....J
- ○ Nucleosomes...........K
- ○ Coiled Fibers..........L
- ○ Chromatin..............M
- ○ Chromosome ....N
- ○ Nucleus................O
- ○ Eukaryotic Cell........P

Must Know Covered...

Chapter 4-5: DNA and Chromosomes

It is important to understand how DNA is packaged into genes and chromosomes since it will help you understand the cycles of condensation and unraveling that occur during mitosis and cell division. It is also important to understand how DNA is arranged into chromosomes because the spatial arrangement of DNA influences gene expression.

In addition, understanding the way in which DNA is coiled into chromosomes will help you understand how more than two meters (about six feet) of DNA fits into forty-six chromosomes in a nucleus that's less than five micrometers in diameter. This plate explores the current model for chromosome organization in eukaryotic cells and shows how DNA is organized with protein in chromosomes.

> Starting at the bottom of the plate, notice the molecule of DNA. The double-stranded molecule will become progressively more coiled and eventually forms the chromosome. We will describe that coiling as we proceed in the plate.

Electron microscopic studies and biochemical research have helped biologists understand how DNA associates with protein to form chromosomes. This packaging enables DNA to direct protein synthesis and replicate, but also prevents it from tangling in the process of mitosis.

Again note the double-stranded molecule of DNA. The **first sugar-phosphate backbone (D)** is at the top, and the **second sugar-phosphate backbone (B)** is at the bottom. These sugar-phosphate backbones should be colored different colors and traced in the DNA molecule until they are no longer visible in the diagram.

Associated with the sugar-phosphate backbones are the four nitrogenous bases of DNA. They are **adenine (A)**, **thymine (T)**, **cytosine (C)**, and **guanine (G)**. Four bold colors should be used to distinguish these **nitrogenous bases (E)**. As you can see, they are initially distinct, but as the DNA molecule condenses, they are more difficult to pinpoint and color, so you might want to trace them.

> We have reviewed the structure of the DNA molecule, and we now move on to show its association with histone proteins, the result of which is the nucleosome. Continue your reading below as you color.

In eukaryotic cells, chromosomes are associated with protei known as histones. **Histone proteins (I)** occur in clusters of eig molecules, as the plate shows. These histones are small, ba proteins that facilitate DNA packaging. The eight histone protei are shown distinctly at first, then for simplicity we show them c lectively as **condensed histones (J)**.

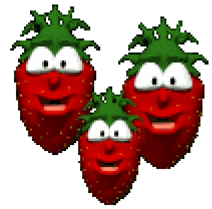
Note in the diagram that **two loops of DNA (H)** surround ea histone. The product of this looping is a unit called a nucleoson Several **nucleosomes (K)** are outlined by a bracket, which sho be colored in a dark color. The nucleosome is the fundamen packing unit for DNA. You should try to color several of the c densed histones and their double loops of DNA.

> Having studied the fundamental packing unit of DNA in the chromosome, we now examine how the nucleosomes combine with one another.

A particular type of protein locks the nucleosomes togethe that DNA cannot unwind from its histone core; the nucleoso remain strung together like beads on a necklace. The windin DNA around the histones shortens its length considerably, but strand must be further shortened if the chromosome is to fit in cell's nucleus. This is accomplished when the nucleosomes further packed into thick **coiled fibers (L)**. A light colo recommended to avoid obscuring these coils.

The coiling of nucleosomes into coiled fibers produces thi fibers that contain even more compact DNA. These fibers are lectively known as **chromatin (M)**. During interphase and e prophase, the DNA of a cell exists as these ultramicrosc fibers, but during late prophase and metaphase, the chron condenses even further. This final compacting produces the t tional **chromosome (N)**. The diagram shows two chromos joined at the centromere just before separation, du anaphase. You can see the **nucleus (O)**, which indicates tha a **eukaryotic cell (P)**. (Few of the details of the cell are shown since we are concentrating on the DNA and the chromosom bacterial cells, DNA exists without protein wrapping.

Strawberry DNA Extraction



Adapted from a lab by C. Sheldon

Introduction:

DNA is found in cells from Animals and Plants. DNA is a double stranded macromolecule composed of nucleotide bases pairing Adenine with Thymine and Guanine with Cytosine. DNA can be extracted from cells by a simple technique with household chemicals, enabling students to see strands of DNA with the naked eye.

Purpose:

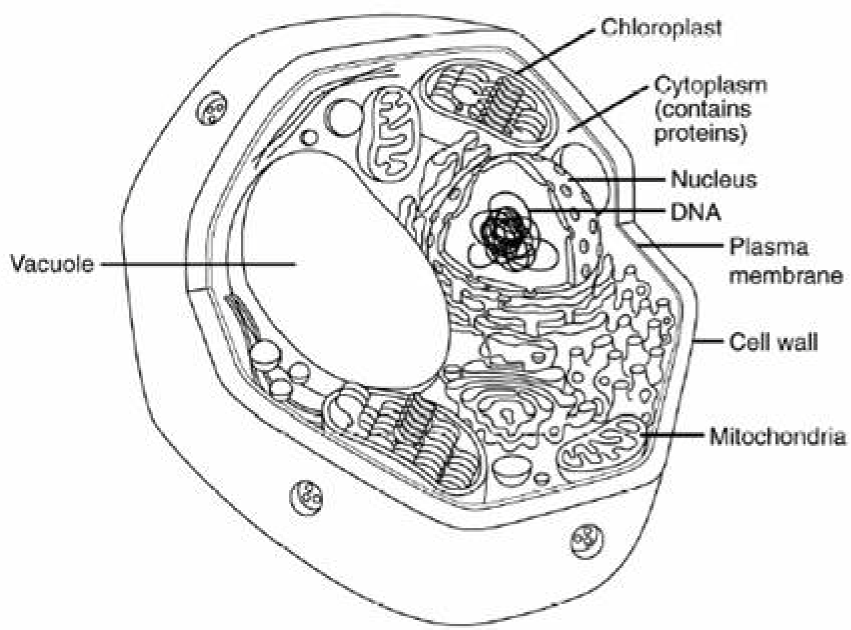
To extract DNA from the fruit of a strawberry plant

Safety Precautions:

- Do not eat or drink in the laboratory.
- Wear Apron & Safety Goggles.

Prelab:

Take a look at the sketch of the plant cell below. The chromosomes (which are made of DNA) are in the nucleus. This is the only place where DNA is located.



Now match the procedure with what it is doing to help isolate the DNA from the other materials in the cell.

_____1. Break open the cell	**A. Squish the fruit to a slush**
_____2. Dissolve cell membranes	**B. Filter your extract through cheesecloth**
_____3. Precipitate the DNA (clump the DNA together	**C. Mix in a detergent solution**
_____4. Separate organelles, broken cell wall, and membranes from proteins, carbohydrates, and DNA	**D. Layer cold alcohol over the extract**

Materials / Equipment (per student group):

1 heavy duty zip-lock baggie

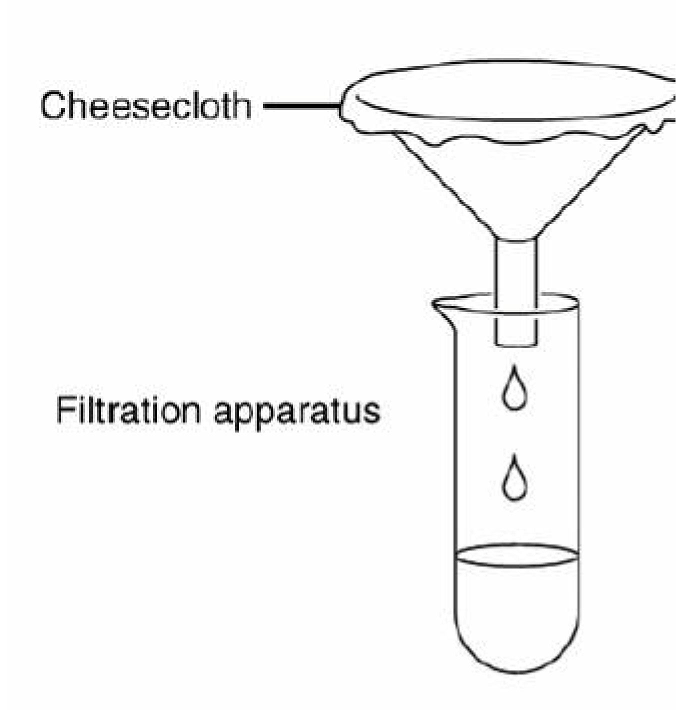
2. 1 strawberry (fresh or frozen and thawed)
3. cheesecloth
4. funnel
5. 100 ml beaker
6. test tube
7. wooden coffee stirrer

Reagents:

1. DNA extraction buffer (One liter: mix 100 ml of shampoo (without conditioner), 15 g NaCl, 900 ml water OR 50 ml liquid dishwashing detergent, 15 g NaCl and 950 ml water)
2. Ice-cold 95% ethanol or 95% isopropyl alcohol

Procedure:

1. Place one strawberry in a zip lock baggie and carefully press out all of the air and seal the bag.
2. Smash the strawberry with your fist for 2 minutes.
3. Add 10 ml extraction buffer to the bag and carefully press out all of the air and seal the bag.
4. Mush again for one minute.
5. Filter through cheesecloth in a funnel into beaker. Support the test tube in a test tube rack.
6. Discard the extra mashed strawberry.



7. Pour filtrate into test tube so that it is 1/8 full.

8. Slowly pour the ice-cold alcohol into the tube until the tube is half full and forms a layer over the top of the strawberry extract.

9. At the interface, you will see the DNA precipitate out of solution and float to the top. You may spool the DNA on your glass rod or pipette tip.

10. Spool the DNA by dipping a pipette tip or glass rod into the tube right where the extract layer & alcohol are in contact with each other. With your tube at eye level, twirl the rod & watch as DNA strands collect.

Questions:

1. **Where can DNA be found in the cell?**

2. **Discuss the action of the soap (detergent) on the cell. What is the purpose of the soap in this activity?**

3. **What was the purpose of the Sodium Chloride? Include a discussion of polarity and charged particles.**

4. **Why was the cold ethanol added to the soap and salt mixture?**

5. **Describe the appearance of your final product?**

6. **Draw a diagram of DNA containing 5 sets of nucleotide bases labeling the hydrogen bonds between the bases.**

Must Know Covered...

Chapter 4-2: Replication of DNA

The result of the cell cycle is the division of the mother cell into two daughter cells. This cell division takes place in almost all types of plant, animal, and microbial cells. Before a cell divides, the DNA in its nucleus replicates to ensure that identical copies of its genes are passed to each of the daughter cells. This replication occurs during the S phase of the cell cycle and has already been completed when mitosis begins. This plate explores the mechanism by which the DNA replicates.

As you look over the plate, note that we are presenting a single illustration of a double-stranded DNA molecule undergoing replication. Many of the colors that were used in the previous plate should be used here. As you read the paragraphs below, color the appropriate structures in the plate.

The DNA molecule is a double helix composed of two strands of DNA. Each strand is made up of alternating deoxyribose molecules and phosphate groups. Forming the rungs on the DNA ladder are the four nitrogenous bases which are connected to the deoxyribose backbone. In the plate, you should use a medium color on the **old deoxyribose-phosphate backbone (O)**; there are two of these backbones, and both should be colored.

After you color the deoxyribose-phosphate backbones of the old DNA molecule, you should select four different colors with which to color the four different nitrogenous bases of the old DNA molecule. These bases are **adenine (A)**, **thymine (T)**, **cytosine (C)**, and **guanine (G)**.

We will now begin the construction of the two new strands of DNA. As you read about the process of their construction, color the appropriate portions of the plate.

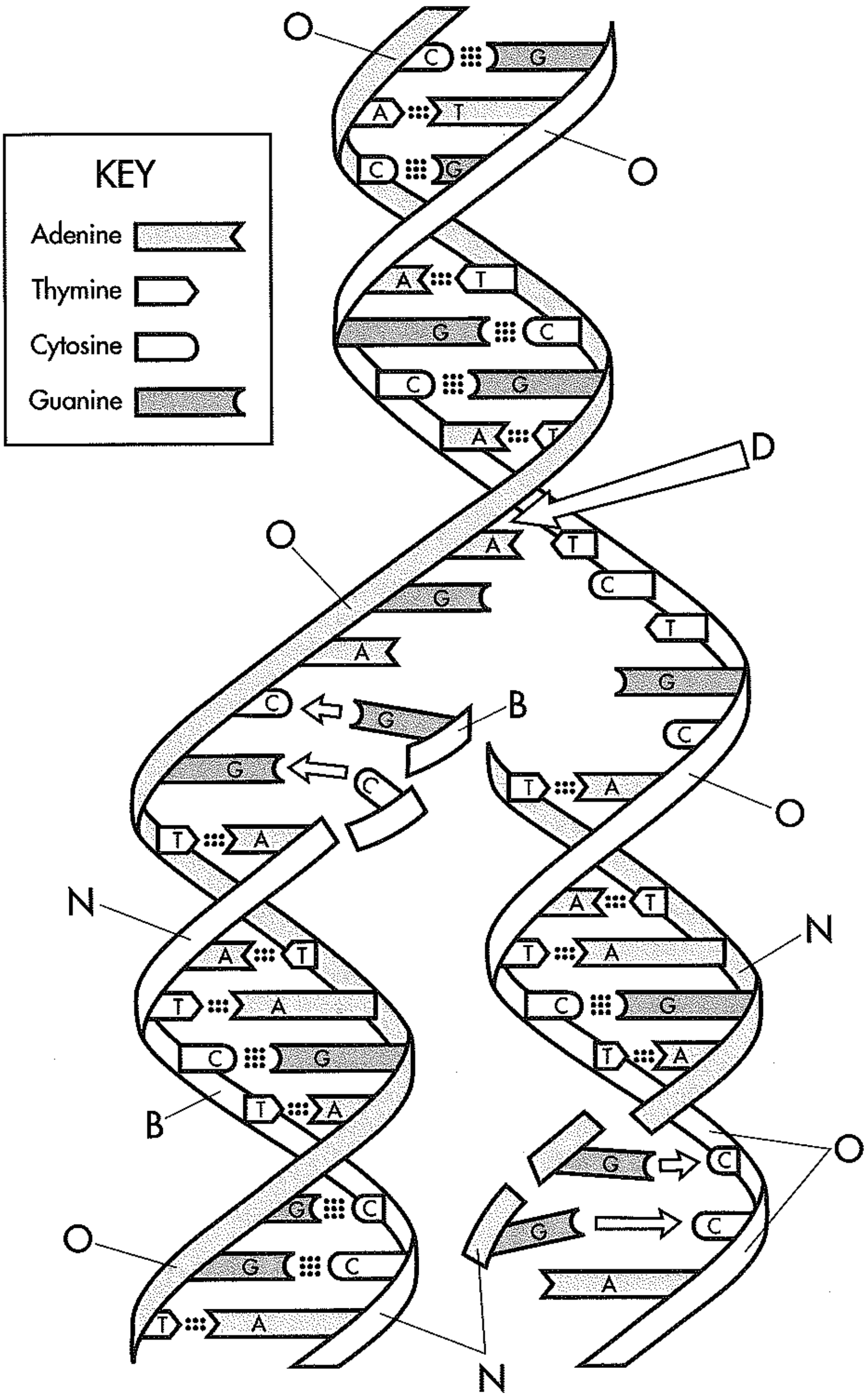
The replication process begins with an uncoiling of the original double-stranded DNA molecule. A specific enzyme untwists the double helix and separates the DNA molecule into its two complementary strands. The site of separation is referred to as the **replication fork (D)**, and an arrow points to it.

Each strand of the DNA molecule now serves as a model, or template, for the construction of a complementary DNA molecule. To construct this complementary DNA molecule, **new deoxyribose-phosphate molecules (N)** will be needed, as well as new base pairs. On the left, notice that the new backbone is being synthesized as the molecule untwists, while on the right side, it is being constructed in the opposite direction, with new molecules being added in fragments, starting at the bottom. The strand on the left is therefore called the leading strand, and the one on the right side is the lagging strand.

We will complete the construction of the two new DNA molecules by mentioning the principle of complementary base pairing. Continue using the colors for the nitrogenous bases that you used above.

Once the deoxyribose-phosphate backbones have been constructed, the nucleotides will join with one another so that base pairing takes place in a specific pattern. Thymine (T) molecules will always pair with adenine (A) molecules, and cytosine (C) will always pair with guanine (G) molecules. Thus, the order of nitrogenous bases on the original template strand determines the order of the bases on the new strands. For example, we see on the left side the base sequence: *C-G-T-T-A-G-A-G-G-T*. These code for a new strand with the base sequence: *G-C-A-A-T-C-T-C-C-A*. As you can see, this is what ensures that each new DNA molecule is identical to its parent strand.

Hydrogen bonding holds the bases of the two strands together, and a double helix forms, so that each new DNA double helix consists of an old strand and a new strand. This method of DNA replication is referred to as semiconservative replication.



Replication of DNA

- O Deoxyribose-Phosphate Backbone (Old) ....O
- O Deoxyribose-Phosphate Backbone (New) ....N
- O Adenine...............A
- O Thymine...............T
- O Cytosine C
- O Guanine...............G
- O Replication Fork ......D

DNA LAB

PRE-LAB DISCUSSION: Deoxyribonucleic acid (DNA) is a long complex molecule that is present in the cells of all living organisms. DNA is the molecule of which genes are made. Understanding DNA is the key to answering a vast number of biological questions. It can explain how chromosomes can duplicate during cell division and transfer their genetic information to the newly formed chromosomes. It can also explain how chromosomes in the nucleus of the cell can direct the formation of specific proteins outside the nucleus.

PURPOSE/PROBLEM: What are the names of the molecules that make up DNA?
How can a model of DNA be constructed to show replication?

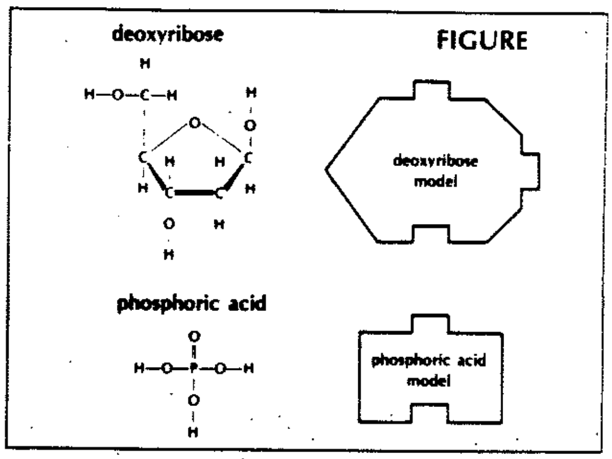
MATERIALS: color coded sheets of paper models
scissors

PROCEDURE:

Part A: Structure of DNA Nucleotides

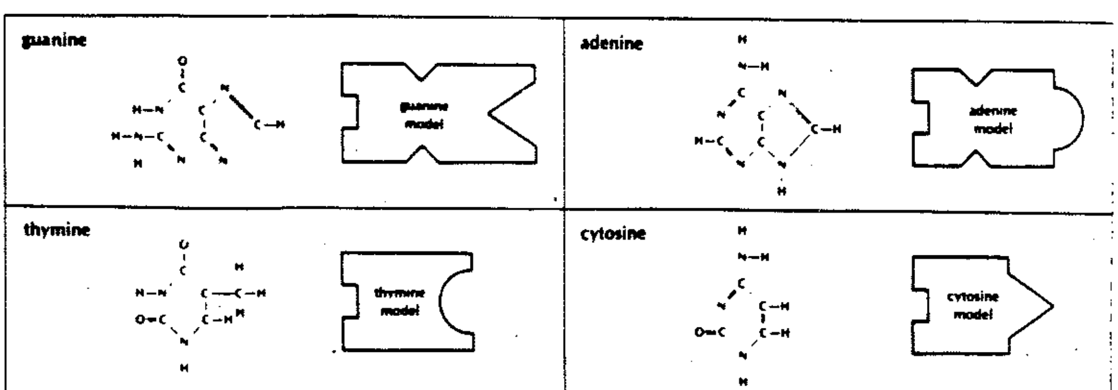
1. Two important molecules which make up DNA are deoxyribose(sugar) and phosphoric acid. Their structural formulas and models are shown in **Figure A,** as well as in your text book. Study these molecules and answer Question 1 found in the **ANALYSIS.**

Figure A



2. In addition, there are four different molecules called nitrogen bases. Their structural formulas and models are shown in **Figure B**, as well as in your text book. Use these to answer **ANALYSIS** Question #2.

Figure B



3. A molecule of deoxyribose joins with phosphoric acid and any one of the four bases to form a chemical compound called a nucleotide. A nucleotide is named for the nitrogen base that joins with the deoxyribose. For example, if guanine attaches to deoxyribose, the molecule is called a guanine nucleotide. Use this information to answer **ANALYSIS** Questions #3-4.

Part B: Structure of a DNA Molecule

4. A DNA molecule is like a twisted ladder. If you have ever visited an old style lighthouse, the spiral stairway is an excellent model for the DNA structure. Deoxyribose and phosphoric acid join to form the sides or uprights of the ladder.

5. Cut out the colored nucleotide models provided by your teacher. CUT ONLY ALONG THE SOLID LINES. CAUTION: Always be careful when using scissors.

6. Fit six nucleotides together in puzzle like fashion to form a vertical row in the following sequence from top to bottom:
   Thymine nucleotide
   Guanine nucleotide
   Cytosine nucleotide
   Cytosine nucleotide
   Adenine nucleotide
   Guanine nucleotide

7. These six half rungs represent only half of the DNA ladder. Complete the right side of the DNA ladder by matching the bases of other nucleotides to form complete rungs. It may be necessary to turn molecules upside down in order to join certain base combination. Now answer **ANALYSIS** Questions #5-11.

Part C: Replication

8. This DNA model represents only a short length of the DNA of a chromosome. An entire chromosome has thousands of rungs, made of these paired nucleotides. This model gives you an idea of how the DNA molecule is designed so that you can see where the DNA code is and how this code can be passed on to new chromosomes in new daughter cells. The making of a new DNA molecule is called DNA replication. Replication occurs before mitosis and meiosis. Several steps can be recognized as replication occurs. Untwisting of the DNA molecule occurs first. You will simulate the next step -unzipping- with your model.

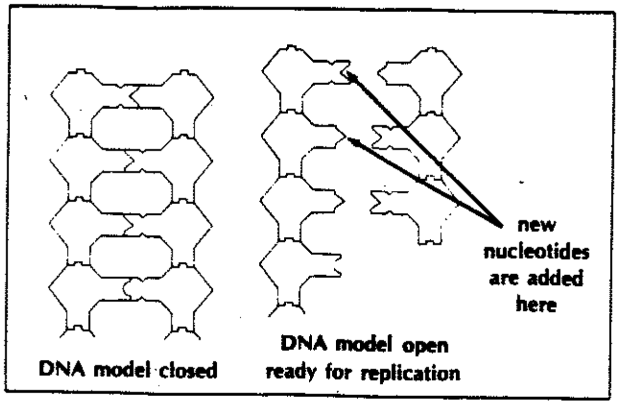
9. Open ("unzip") your DNA model along the points of attachment between base pairs (rungs) and separate the two ladder halves.

10. Using the left half of your model as a guide, add new nucleotides to form a new right side.

11. Build a second DNA model by adding new unattached nucleotides to the right half of the original model. See **Figure C.**

12. Answer **ANALYSIS** Questions #12 -16.

Figure C



Part D: The DNA code

13. Besides ensuring the exact duplication of chromosomes, the order of paired bases are a genetic code. This code is a set of instructions for the entire cell's structure and functioning. This code is read at the ribosomes so that certain proteins can be made there. These proteins determine what the cell will become or what traits the individual will have.

14. Answer **ANALYSIS** Questions #17-18

15. Arrange the nucleotide order and make a different DNA code using one of your DNA models. This is similar to using the letters in our alphabet. By switching letter placement entirely new words are spellled. For example: feat or fate.

16. Complete **ANALYSIS** Question #19.

ANALYSIS: (Answer the following on your own paper with complete sentences.)

Part A

1. Give the simple (chemical, molecular) formula for: (a) deoxyribose (b) phosphoric acid.
2. Of the four bases, which other base most resembles: (a) adenine? (b) thymine?
3. List the names of the four possible nucleotides.
4. Explain in what manner all the nucleotides are alike and what in specific makes them different.

Part B

5. If DNA is ladderlike, which two molecules form the sides?
6. To which molecule does the base attach?
7. Name the molecules of each nucleotide that form the rungs of the ladder model.
8. Is the order of the half-rung bases exactly the same from top to bottom of each side of your model?
9. Only two combinations of base pairings are possible for the rungs. Name these two combinations.
10. If four guanine bases appear in a DNA model, how many cytosine bases should there be?

11. The following are the bases on the left of a DNA molecule. List the bases that would make up the right side.

thymine __________
adenine __________
guanine __________
guanine __________
cytosine __________

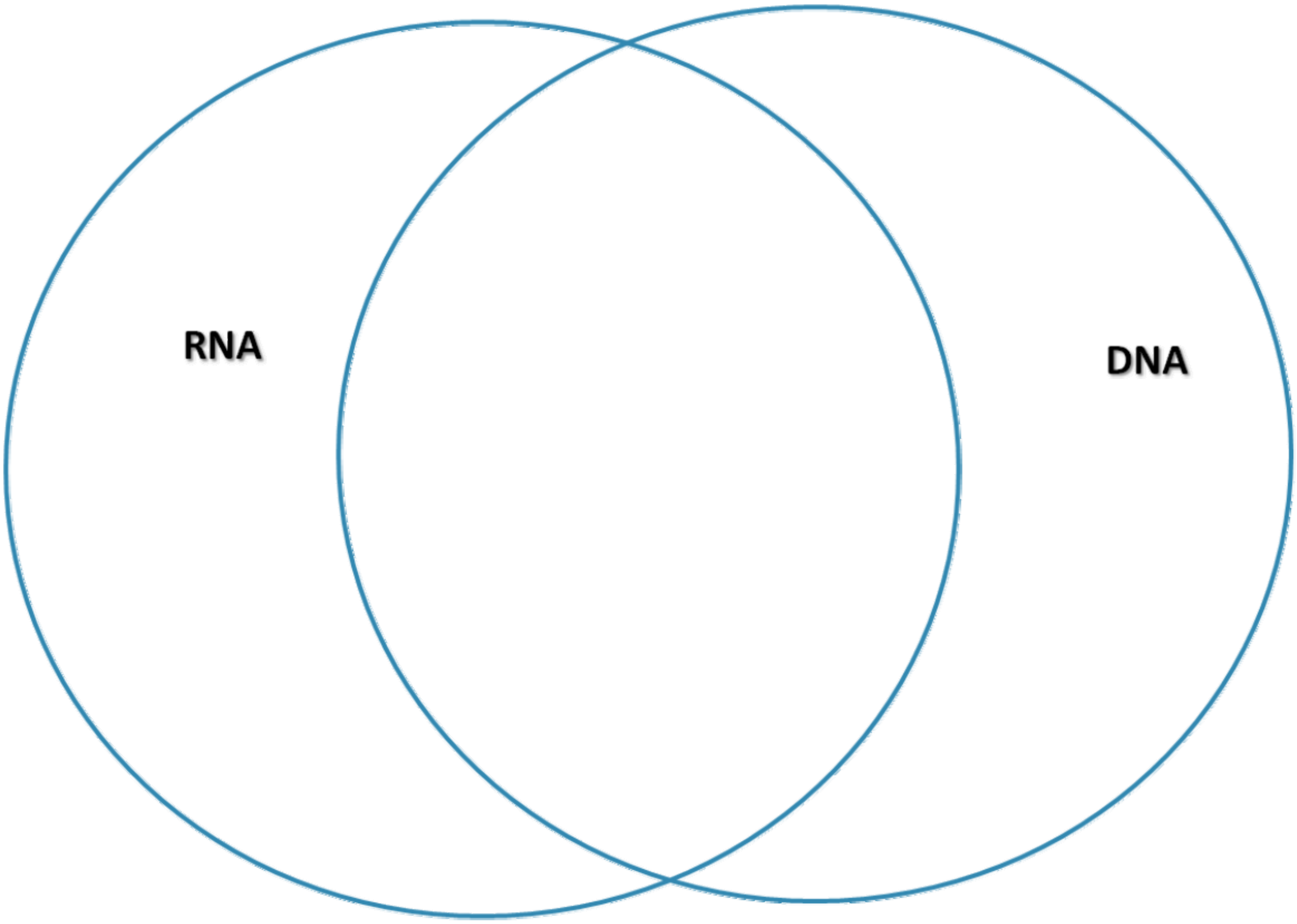
Part C

12. Do the two molecules contain the same number of rungs?
13. Is the order from top to bottom of the base pairs the same for each new DNA molecule?
14. How many molecules of adenine and thymine are in each of the new DNA molecules?
15. Do the numbers agree?
16. Are the two DNA molecules exactly alike?

Part D

17. Where is the genetic code read or translated?
18. What is the substance that is produced at the ribosome that can result in visible traits or characteristics?
19. List the new genetic code that you made with your DNA model.

CONCLUSION: Write two to three paragraphs answering the original lab problems? Include responses to the following three questions.
(What is DNA replication? Why is DNA replication necessary? What information is coded in the complex molecule?)



Made in Nucleus Adenine Stays in Nucleus

Double Stranded

Leaves Nucleus Guanine

Ribose

Phosphate

Thymine

Cytosine

Uracil

Single Stranded

Deoxyribose

84
DNA TRANSCRIPTION

The process in which the hereditary code carried by DNA is used by the cell to control protein synthesis has turned out to be quite complex. It involves three different types of a slightly different nucleic acid, called RNA, and two sequential processes known as transcription and translation.

Color the headings DNA and RNA and titles and structures D, T, R, and U. Use the D and T colors from the previous plates and light colors for R and U.

RNA (ribonucleic acid) is made up of numerous nucleotides assembled in exactly the same way as in DNA except that RNA is mostly single-stranded and mostly not in the form of a helix. It differs in composition in that the sugar component is *ribose,* rather than *deoxyribose,* and that the base *thymine* is replaced by *uracil,* a different, though quite similar, molecule. The other three bases are the same as in DNA: adenine, cytosine, and guanine.

Color the heading Transcription and titles P, A, C, G, H, B, and E. Use the established colors from the previous plates for P through H and a very light color for B. Color the associated illustration.

The first step in utilizing the DNA code is the process of transcription. In transcription, the DNA unzips, just as if it were going to be replicated (Plate 83), except that instead of DNA polymerase attaching to it, a different enzyme, called *RNA polymerase,* attaches, synthesizing a molecule of RNA instead of a molecule of DNA. Only one side of the DNA molecule is transcribed. This is assured by the fact that RNA polymerase is not attracted to just any stretch of DNA but only to certain DNA base sequences, called "promoters." Promoters are sequences of bases that do not determine protein structure but serve only to convey the message "RNA polymerase, start here."

The transcription process is essentially identical to replication. The differences are that the complementary daughter strand is being assembled with ribonucleotides instead of deoxyribonucleotides and that the RNA daughter strand does not remain attached to the parent DNA strand. Instead it separates from the DNA, and the DNA then zips back together. The RNA migrates out of the nucleus of the cell to the cytoplasm.

Three different classes of RNA are made in this way. The most abundant class is called messenger RNA (abbreviated mRNA) because it carries the message of what amino acids are to be put together in what sequence to make the cell's proteins. The second class is ribosomal RNA (rRNA), which is an important component of the ribosomes, the organelles that actually accomplish the synthesis of the cell's proteins. The third class is called transfer RNA (tRNA) because it transfers the amino acids to the ribosome for assembly into proteins. The RNA molecule being synthesized in the center of this plate could belong to any of the three classes of RNA. They are all alike except in length and the sequence of bases. Messenger RNA varies in length according to the number of amino acids in the protein for which it carries the code, but it is typically from 900 to 1500 nucleotides in length. It is mostly linear, although it can fold back on itself, and a few short sections may form a helix where the bases are complementary.

Ribosomal RNA takes only certain specific lengths, approximately 120, 1500, and 3000 nucleotides in prokaryotic cells and approximately 120, 160, 2000, and 5000 in eukaryotic cells. It is extensively folded back and forth upon itself, because it forms a framework for the attachment of a number of protein molecules to form the somewhat globular ribosome, which is slightly more than half rRNA by weight and slightly less than half protein.

Color the heading Transfer RNA, title F, and the remainder of the plate.

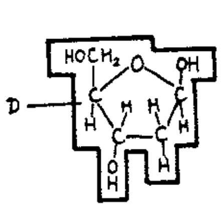
Transfer RNA deserves some special attention because of its peculiar structure. There must be at least one different kind for each amino acid (actually a few more than that), all are about 80 nucleotides in length, all end in the sequence CCA (cytosine, cytosine, adenine) on their 3′ ends, that end always serves as the attachment point of the amino acid to be transferred, and all tRNAs are folded into a complex "hairpin" structure with most of the molecule in helix form but three loops of unpaired bases.

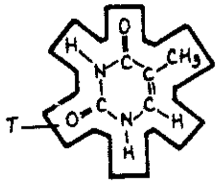
The center loop has a set of three unpaired bases known as the *"anticodon"* (see next plate), which serves as a "recognition code" and assures that that particular tRNA is attracted only to a particular complementary set of three bases on the mRNA, known as a "codon." The unpaired bases on one of the other loops serve to attach the tRNA to the ribosome, and the bases on the third loop serve as a recognition code for the specific aminoacyl-tRNA synthetase enzyme that attaches a particular amino acid to a particular tRNA molecule. The correct protein will be synthesized only if each of these recognition codes is correct.

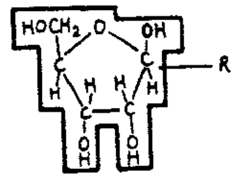
DNA TRANSCRIPTION.

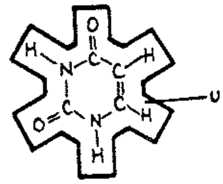
DNA★
DEOXYRIBOSE D
THYMINE T

RNA★
RIBOSE R
URACIL U

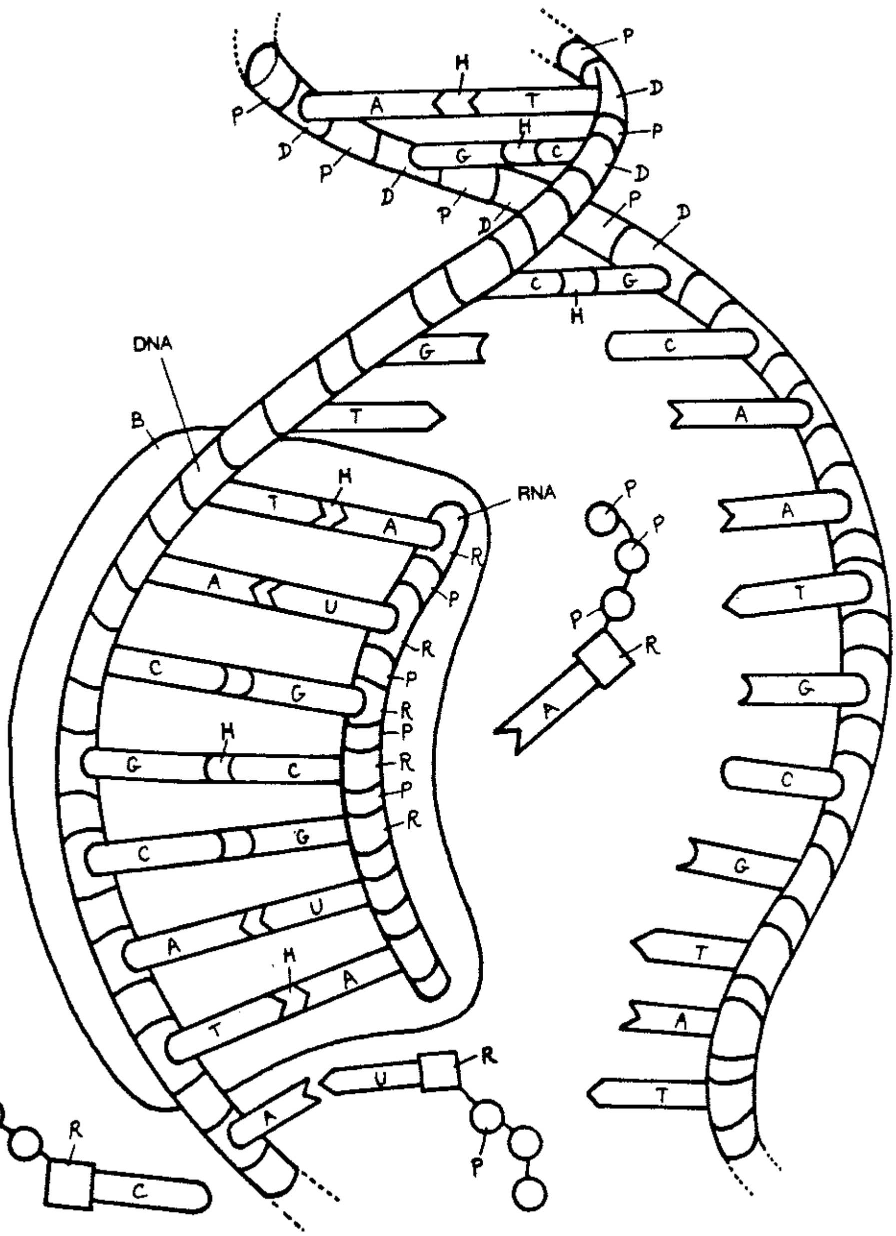


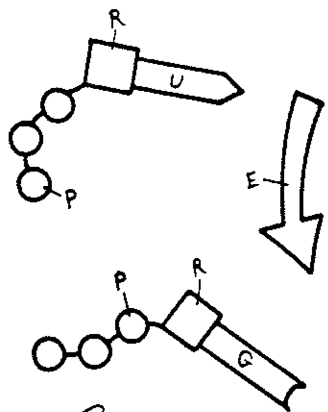


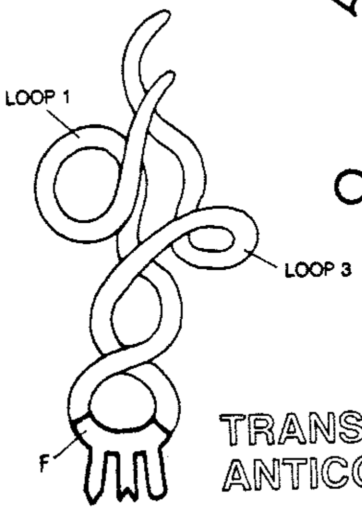




TRANSCRIPTION★
PHOSPHATE P
ADENINE A
CYTOSINE C
GUANINE G
HYDROGEN BOND H
RNA POLYMERASE B
DIRECTION OF TRANSCRIPTION E







TRANSFER RNA★
ANTICODON F

Must Know Covered...

Chapter 4-10: Protein Synthesis (Translation)

Deoxyribonucleic acid (DNA) is the starting point for the important cellular process in which protein is constructed from single amino acids. The protein created can be an enzyme, structural material, or used for virtually any other cell need.

During transcription, the sequence of the nitrogenous bases of DNA directs the production of a strand of messenger RNA (mRNA). Then, in the process of translation, the strand of mRNA determines the sequence of amino acids, which determines the identity of the protein.

Translation is a complex process in which many things occur at the same time. To make the process clearer, we have depicted it as a sequential series of events taking place in the cytoplasm of the cell.

As you may recall, transcription begins with the production of a molecule of mRNA, which travels out into the cytoplasm to take place in translation.

Once it is in the cytoplasm, the mRNA strand complexes with a ribosomal complex. Take a look at the plate; first color the **ribose-phosphate backbone (B)** of the mRNA, and the nitrogenous bases; **adenine (A)**, **cytosine (C)**, **guanine (G)**, and **uracil (U)**. As you can see, the mRNA molecule is associated with the **ribosomal complex (D)**. In the eukaryotic cell, ribosomes are near the endoplasmic reticulum, while in prokaryotic cells, such as bacteria, ribosomes float freely in the cytoplasm.

The mRNA molecule is now anchored within the ribosomal complex of the cell. Each group of three bases in a strand of mRNA is called a codon, and each codon specifies a particular amino acid in a polypeptide chain. We will now see how these codons are involved in the production of polypeptides.

While the mRNA-ribosome complex is assembling, many other important activities are occurring in the cytoplasm. For instance, tRNA (transfer RNA) subunits are binding loosely with particular amino acids in energy-requiring processes.

We can see in the diagram, for example, that the amino acid **alanine (E)** has united with the **tRNA for alanine (E_1)**, and one molecule of **lysine (F)** is floating free, while another has united with a **tRNA molecule for lysine (F_1)**. Notice that different tRNA molecules have different three-base sequences. These are called anticodons. For instance, for alanine, the tRNA has an anticodon of A-U-G, while for lysine, the anticodon is C-C-C.

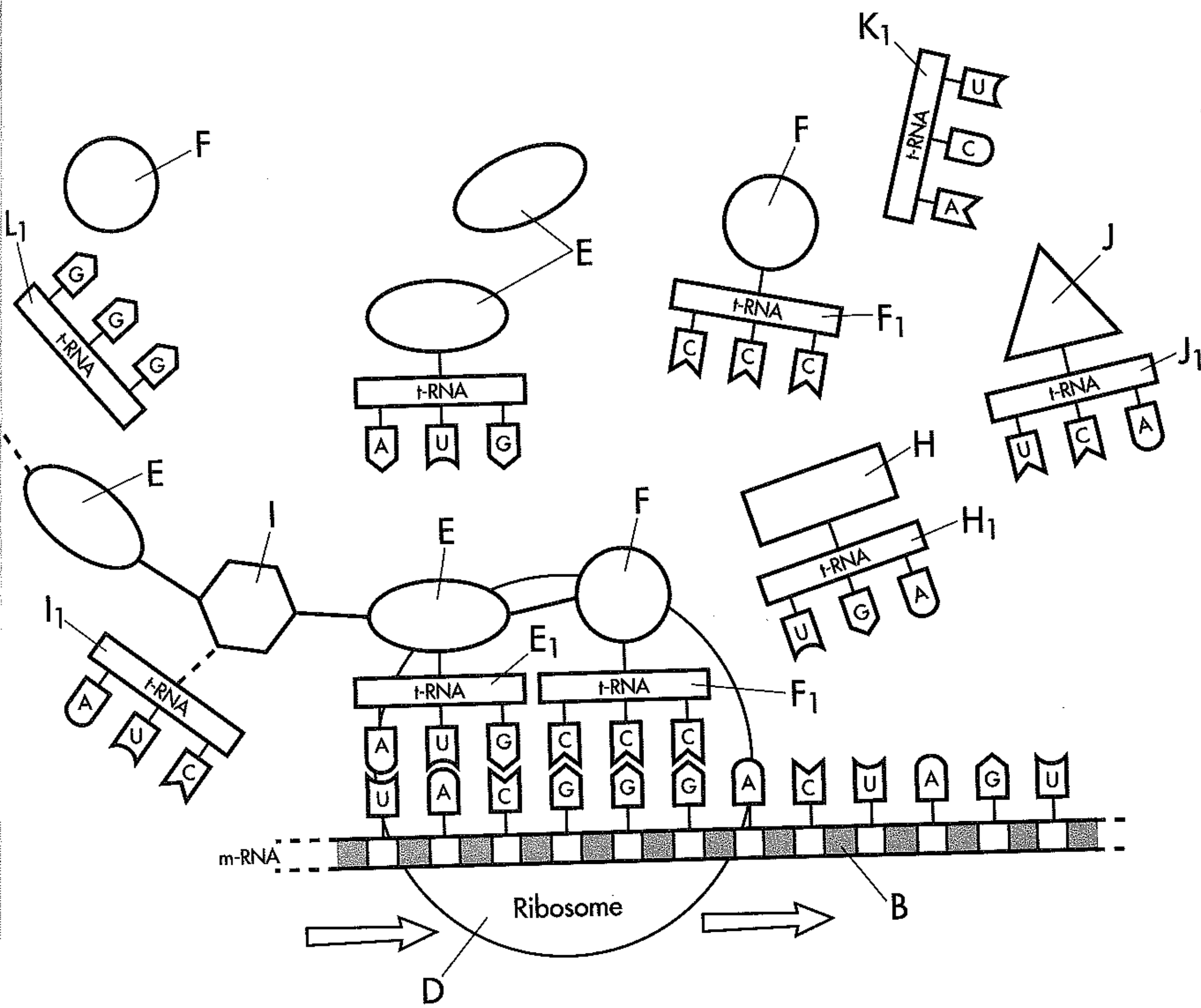
Also in the cytoplasm is a molecule of **tryptophan (H)** united with the **tRNA molecule for tryptophan (H_1)**, and a **valine (J)** that is united with the **tRNA for valine (J_1)**. Note that there is no tyrosine molecule shown for the **tRNA for tyrosine (K_1)**, nor is there a leucine molecule available for the **tRNA for leucine (L_1)**.

Having established the specificity of amino acids for their tRNA molecules, we now show how these complexes function in the translation process.

Once bound to their amino acids, the tRNA molecules travel tc the ribosome where the mRNA molecule is anchored. The critica step is the matching of the codon on the mRNA molecule with th anticodon on the tRNA molecule. When this is accomplished, certain amino acid is brought into position. For example, we se the amino acid lysine (F) attached to its tRNA molecule (F_1). Th anticodon of the tRNA is complementary to the codon of th mRNA, and lysine is placed into position. Immediately to its le an alanine (E) has been put into place by its tRNA (E_1). The al nine molecule is bonded to a **serine molecule (I)** which is in t process of breaking free from its **tRNA molecule (I_1)**, and at t far left, an alanine molecule (E) has already detached from tRNA. Note how the process unfolds as you color. Can you gu which amino acid will follow after the tryptophan?

As the arrow indicates, the ribosome moves along the mRN ensuring that each codon and anticodon matches. Enzyr create peptide bonds between the amino acids to form polypeptide of increasing length. The translation process ter nates when specific codons on the mRNA molecule signal a At this point the polypeptide is released from the ribosome an further processed to yield a functional protein.

Protein Synthesis (Translation)



Protein Synthesis (Translation)

- ○ Ribose-Phosphate Backbone .... B
- ○ Adenine................ A
- ○ Cytosine C
- ○ Guanine................ G
- ○ Uracil .... U
- ○ Ribosomal Complex...... D
- ○ Alanine................ E
- ○ tRNA for Alanine...... E_1
- ○ Lysine .... F
- ○ tRNA for Lysine ...... F_1
- ○ Tryptophan .... H
- ○ tRNA for Tryptophan .. H_1
- ○ Serine I
- ○ tRNA for Serine ...... I_1
- ○ Valine .... J
- ○ tRNA for Valine ...... J_1
- ○ tRNA for Tyrosine .... K_1
- ○ tRNA for Leucine...... L_1

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Protein Synthesis

Protein synthesis is a complex process. In this activity you will trace the steps that are involved in the protein synthesis of a part of a molecule of oxytocin. Oxytocin is the pituitary hormone that helps regulate blood pressure, stimulates the uterus to contract during childbirth, and stimulates the production of milk after childbirth.

A. Protein synthesis begins with DNA in the nucleus. Below is a DNA sequence that could code for part of a molecule of oxytocin. Write the sequence of messenger RNA (mRNA) codons that would result from the transcription of this portion of DNA. The arrow marks the starting point.

↓									
ACA	**ATA**	**TAG**	**CTT**	**TTG**	**ACG**	**GGG**	**AAC**	**CCC**	**ATT**
1	2	3	4	5	6	7	8	9	10

mRNA

____

B. After transcription, mRNA attaches to a ribosome, where translation takes place. Each codon of mRNA bonds with an anticodon of a transfer RNA (tRNA) and each tRNA molecule bonds with a specific amino acid. The table below shows the mRNA codons and the amino acids for which they code. For example, if you were given the codon AGA, you can see from the table that these bases code for the amino acid arginine.

Second Base in Code

First Base in Code	A	G	U	C	Third Base in Code
A	Lysine	Arginine	Isoleucine	Threonine	A
	Lysine	Arginine	Methionine	Threonine	G
	Asparagine	Serine	Isoleucine	Threonine	U
	Asparagine	Serine	Isoleucine	Threonine	C
G	Glutamic acid	Glycine	Valine	Alanine	A
	Glutamic acid	Glycine	Valine	Alanine	G
	Aspartic acid	Glycine	Valine	Alanine	U
	Aspartic acid	Glycine	Valine	Alanine	C
U	STOP	STOP	Leucine	Serine	A
	STOP	Trytophan	Leucine	Serine	G
	Tyrosine	Cysteine	Phenylalanine	Serine	U
	Tyrosine	Cysteine	Phenylalanine	Serine	C
C	Glutamine	Arginine	Leucine	Proline	A
	Glutamine	Arginine	Leucine	Proline	G
	Histidine	Arginine	Leucine	Proline	U
	Histidine	Arginine	Leucine	Proline	C

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Use your mRNA sequence from **A** to write the sequence of amino acids in this part of the oxytocin molecule.

↓

____

____

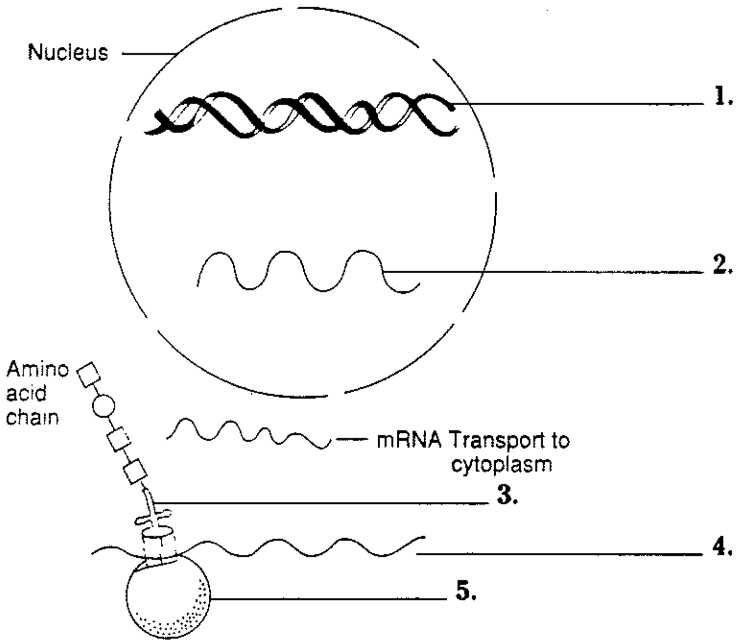
1. How many amino acids make up this portion of the oxytocin molecule? ____________

2. What is the purpose of the UAA codon?

____

____

C. In order to get another view of the entire process of protein synthesis, label the structures on the diagram below.



D. To complete the chart below, give the name and a brief description of each step in protein synthesis that occurs in the part of the cell shown in **C.**

Part of cell	Name of Protein Synthesis Process	Description
Nucleus		
Ribosome		
Cytoplasm		

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Back Print

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Skills Worksheet

Test Prep Pretest

Complete each statement by writing the correct term or phrase in the space provided.

1. In 1928, Frederick Griffith found that the capsule that enclosed one strain of *Streptococcus pneumoniae* caused the microorganism's

______________________ .

2. Avery's experiments demonstrated that DNA is the ______________________ material.

3. After infecting *Escherichia coli* bacteria with ^{32}P-labeled phages, Hershey and Chase traced the ^{32}P. The scientists found most of the radioactive substance

in the ______________________ .

4. Watson and Crick used the X-ray ______________________ photographs of Wilkins and Franklin to build their model of DNA.

5. The process of making new DNA is called ______________________ .

6. The point at which the double helix separates during replication is called

the ______________________ ______________________ .

7. DNA replication occurs during the ______________________ phase of the cell cycle.

8. Eukaryotic DNA contains many replication forks working in concert,

whereas prokaryotic DNA contains only ______________________ replication forks during replication.

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Name ______________________ Class ______________ Date ______________

Test Prep Pretest *continued*

In the space provided, write the letter of the description that best matches the term or phrase.

______ **9.** transformation

______ **10.** replication

______ **11.** DNA helicase

______ **12.** Wilkins and Franklin

______ **13.** Watson and Crick

______ **14.** DNA polymerase

______ **15.** Avery

______ **16.** Griffith

a. discovered the three-dimensional structure of DNA with the help of other scientists

b. proofreads DNA during replication

c. developed high quality X-ray diffraction photographs of DNA

d. results in two DNA molecules that are identical to the original DNA molecule

e. results in a change in a cell's genotype

f. demonstrated that DNA is the material responsible for transformation

g. discovered transformation in bacterial cells

h. unwinds the two DNA strands during replication

Read each question, and write your answer in the space provided.

17. Relate the role of base-pairing rules to the structure of DNA.

____

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____

18. Describe the components of a nucleotide.

____

____

____

19. What happened when Griffith mixed harmless living *R* bacteria with harmless heat-killed *S* bacteria and then injected mice with this mixture?

____

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Name ______________________ Class ______________ Date ____________

20. How did Avery's experiment identify the material responsible for transformation?

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21. Why did Hershey and Chase use radioactive elements in their experiments?

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22. Explain how DNA polymerase "proofreads" a new DNA strand.

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23. Describe the role of DNA helicases during replication.

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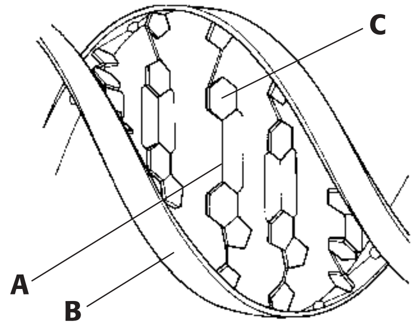
Name ______________________ Class ______________ Date ______________

Test Prep Pretest *continued*

Questions 24 and 25 refer to the figure below.



24. What does the figure above represent?

____

____

25. Identify the structures labeled *A*–*C*.

____

____

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Name ______________________ Class ______________ Date ______________

Skills Worksheet

Test Prep Pretest

Complete each statement by writing the correct term or phrase in the space provided.

1. Instead of the base thymine found in DNA, RNA has a base called ______________________ .

2. Transcription begins when an enzyme called ______________________ ______________________ binds to the beginning of a gene on a region of DNA called a promoter.

3. The instructions for building a protein are written as a series of three-nucleotide sequences called ______________________ .

4. During translation, the area of the ribosome called the ______________________ site receives the next tRNA molecule.

5. Because of its position on the operon, the ______________________ is able to control RNA polymerase's access to the structural genes.

6. The *lac* operon is switched off when a protein called a(n) ______________________ is bound to the operator.

7. In eukaryotic gene regulation, proteins called ______________________ ______________________ help arrange RNA polymerases in the correct position on the promoter.

8. In eukaryotes, long segments of nucleotides with no coding information are called ______________________ .

9. In eukaryotes, the portions of a gene that are actually translated into proteins are called ______________________ .

10. Insertions, deletions and point mutations are types of ______________________ ______________________ .

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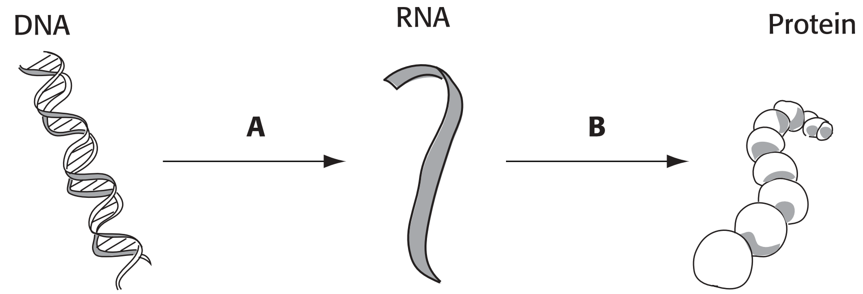
Questions 11–13 refer to the figure below.



11. The processing of information from DNA into proteins, as shown above, is referred to as ______________ ______________ .

12. Stage *A* is called ______________ .

13. Stage *B* is called ______________ .

In the space provided, write the letter of the term or phrase that best completes each statement or best answers each question.

_____ **14.** In what kinds of cells do mutations occur?
- **a.** body cells
- **b.** gametes
- **c.** reproductive cells
- **d.** All of the above

_____ **15.** A mutation that moves a gene to a new location is called a(n)
- **a.** point mutation.
- **b.** insertion.
- **c.** transposon.
- **d.** deletion.

_____ **16.** Which of the following represents the codons that correspond to this segment of DNA: TATCAGGAT?
- **a.** AUA—GUC—CUA
- **b.** ATA—GTC—CTA
- **c.** AUAGU—CCUA
- **d.** ACA—CUC—GUA

_____ **17.** Which of the following are the anticodons that correspond to the mRNA codons CAG—ACU—UUU?
- **a.** GTC—TGA—AAA
- **b.** GUC—UGA—AAA
- **c.** glutamine—threonine—phenylalanine
- **d.** GAC—UCA—AAA

_____ **18.** Because the genetic code is the same in all organisms, it appears that
- **a.** the genetic code evolved more than once.
- **b.** the codon GUC codes for different proteins in different organisms.
- **c.** thymine will soon replace uracil in RNA.
- **d.** all life-forms have a common ancestor.

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Name ______________________ Class ______________ Date ______________

Test Prep Pretest *continued*

Read each question, and write your answer in the space provided.

19. Explain how RNA differs from DNA.

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20. Summarize the process of translation.

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21. Describe the functions of RNA.

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22. What is the *lac* operon?

____

____

23. Explain why gene regulation in eukaryotic cells is more complex than in prokaryotic cells.

____

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____

____

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Name ______________________ Class ______________ Date ____________

Test Prep Pretest *continued*

24. Why do scientists think that introns and exons contribute to evolutionary flexibility?

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25. Describe the three ways that mutation can alter genetic material.

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